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SIMULATION MODEL RESULTS FOR ENERGY AND MOBILITY IMPACT OF BEHAVIORAL SCENARIOS IN POLARIS

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PROJECT OVERVIEW

Timeline	Barriers
• Project start date : Oct. 2016 • Project End date : Sep. 2019 • Percent complete : 100%	• High uncertainty in technology deployment, functionality, usage, impact at system level • Computational models, design and simulation methodologies • Lack of data on individual behaviors relating to CAV adoption and usage • Integration of disparate model frameworks
Budget	**Partners**
• FY17-FY19 Funding: 1,410,000 • FY17 Funding Received: 400,000 • FY18 Funding Received : 375,000 • FY19 Funding Received : 635,000	• Argonne (Lead) • University of New South Wales • University of Illinois at Chicago • ORNL, LBNL • Chicago DOT and Chicago Metropolitan Agency for Planning (Local Stakeholders) • Federal Transit Administration

PROJECT RELEVANCE

FY17
- Vehicle adoption
- Value of travel time
- Time use
- Telecommuting

FY18
- Vehicle sharing
- Multi-modal travel
- How will decision making (mode choice, destination choice, timing, etc.) change?

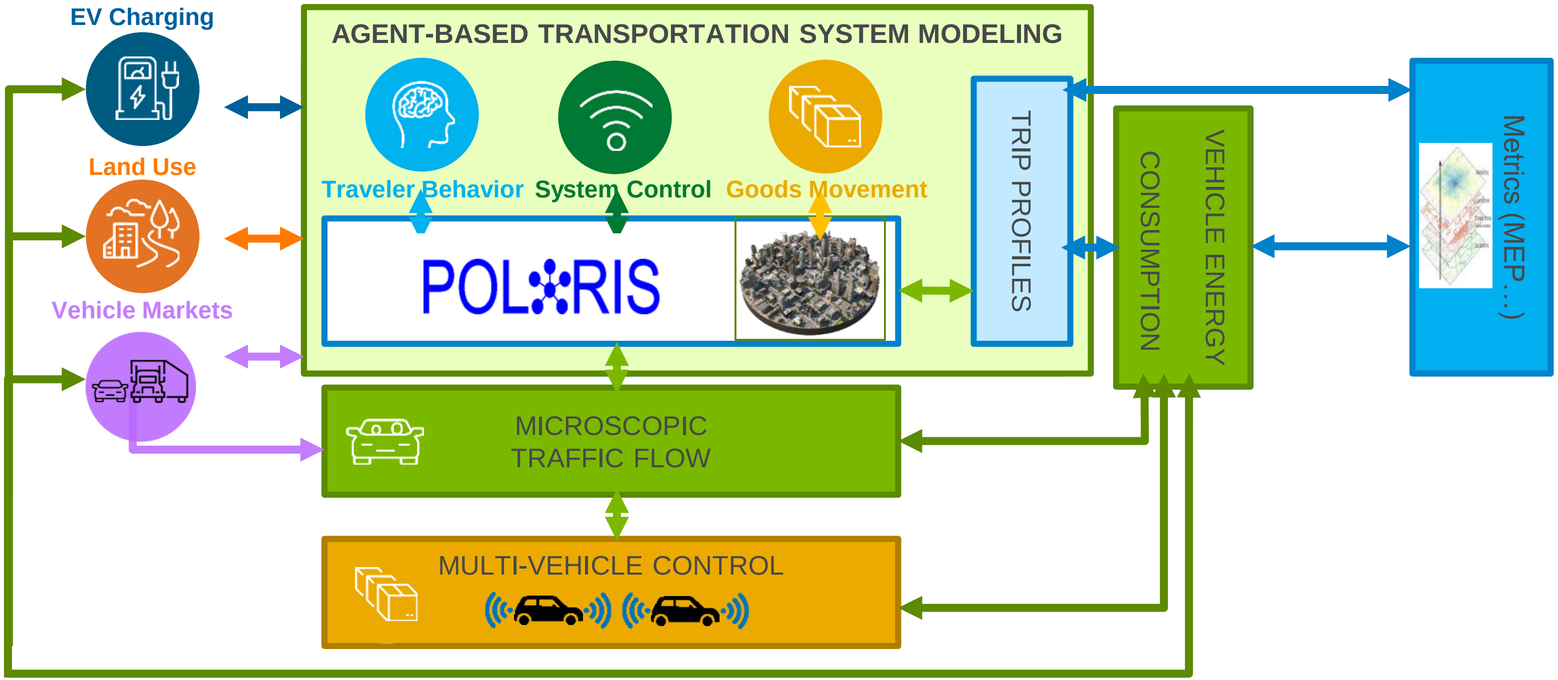
FY19
- TNC / ride-sharing behavior
- Time use and time value changes from CAV
- Long-term decisions

Challenges:
- Traveler decision making is a high source of uncertainty for impact of advanced mobility
- Limited data exists on behavioral response to CAV and other future mobility technologies
- High degree of interconnection between decision-making, transportation system performance and development of Smart Mobility technologies

Objectives and Relevance:
- Considering the **behaviors of individual** travelers at multiple timeframes
- Assessing the effect of traveler decisions on **mobility energy productivity** for future mobility
- Key goal of **reducing uncertainty** of MEP changes due to decision-making for VTO analysis
- **Multi-dimensional analysis** incorporating decision-making is req

APPROACH

Answer Complex Questions through High Fidelity System Simulation



MILESTONES

18Q3

Milestone 1:
Parameter estimates for time value, time-use impacts of new mobility modes, from currently available data, disaggregated by use group

18Q4

Milestone 2:
Empirical behavioral analysis for time use and travel demand impact of new mode choice options

19Q1

19Q2

Milestone 3:
Implementation of new activity generation and planning models accounting for time use/vott changes

19Q3

Milestone 5:
Study of SAV-transit cooperation/competition

19Q4

Milestone 6:
Quantification of energy, mobility and MEP of the impact of time use changes due to VOTT shifts, new modal options, new activity options, etc, due to technology

TECHNICAL ACCOMPLISHMENTS

- **Enhanced POLARIS Capabilities**
- **Estimated the impact of 13 future scenarios**

WORKFLOW IMPLEMENTATION USING POLARIS IS UNIQUE

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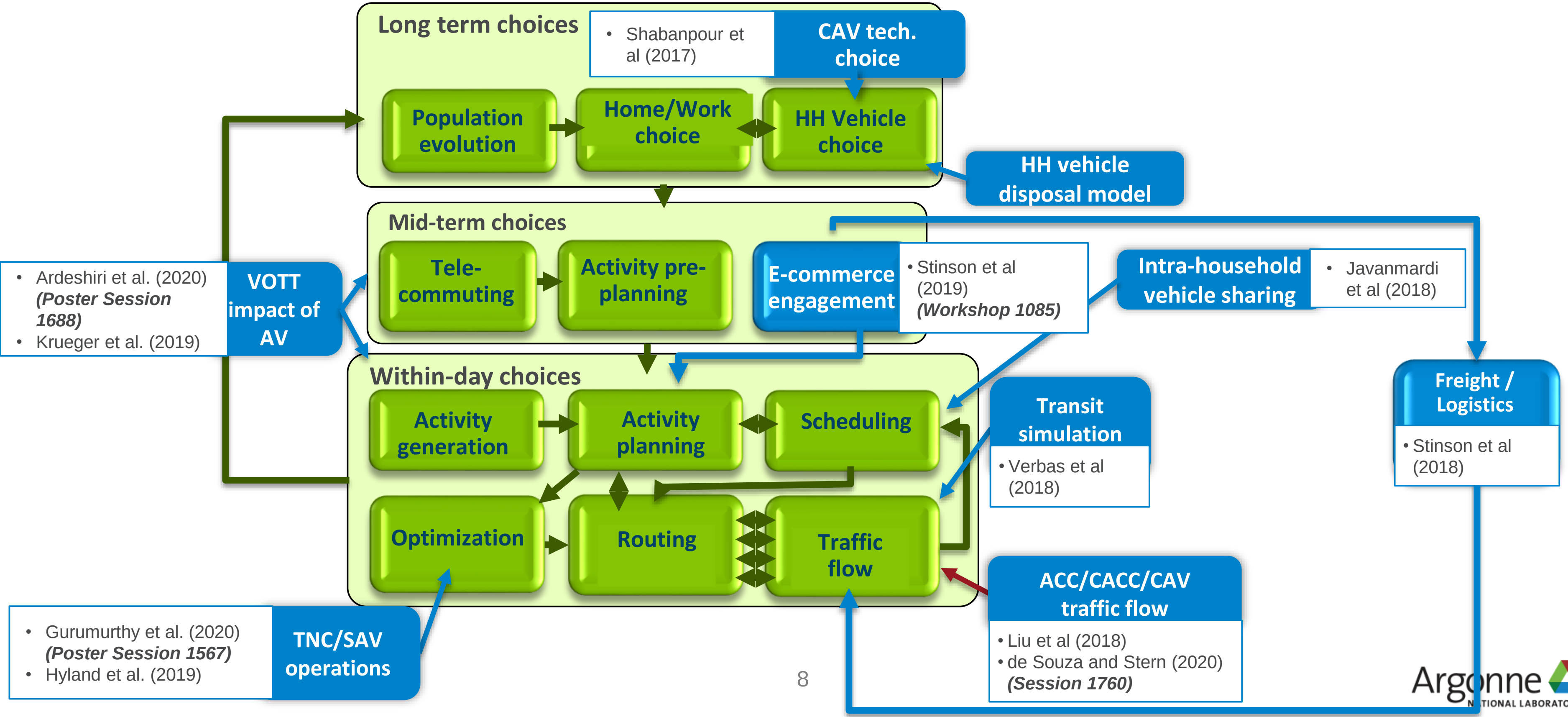
POLARIS

- **Key modeling features:**
  - Full-featured **activity-based** model
  - Includes **freight** shipments and local deliveries
  - High-fidelity **vehicle energy** consumption
  - **Integrated** demand, network assignment and traffic flow
  - **EV charging** and **grid** integration
  - Connection to **UrbanSIM** land use
  - Traveler behavior impacts of **VOTT** across many choices

Computational performance:

- Fully **agent-based**
- Integration with external **optimization** solvers (CPLEX, Gurobi, GLPK)
- High-performance **C++ codebase**
- Large-scale models with **100% of agents**
- **4-6 hr runtime** for up to 10 million agents
- Cross-platform implementation can run on Linux **HPC** clusters

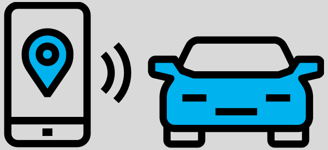
POLARIS HAS BEEN SUBSTANTIALLY ENHANCED FOR FUTURE MOBILITY



SCENARIOS CONSIDERED

A world of

HIGH SHARING, PARTIAL AUTOMATION (Sharing)

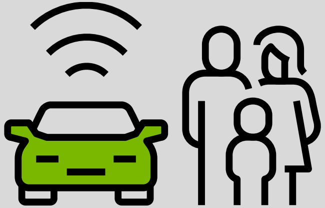


New technology enables people to significantly increase the use of **transit, ride-hailing** and **multi-modal travel. Partial automation** is introduced and is primarily used on the highway.

HIGH SHARING, HIGH AUTOMATION (SAV)

Technology has taken over our lives, enabling **high usage of fully automated driverless vehicles, ride-hailing and multi-modal trips**, which are convenient and inexpensive. As a result, **private ownership has decreased** and **e-commerce has increased**.

LOW SHARING, HIGH AUTOMATION (Private-AV)



Fully automated privately owned driverless vehicles dominate the market. The ability to own AVs leads to **low ride-sharing** and an expansion of urban/sub-urban boundaries, while **e-commerce has increased.**

HIGH LEVEL SCENARIO RESULTS – MOBILITY AND ENERGY IMPACT

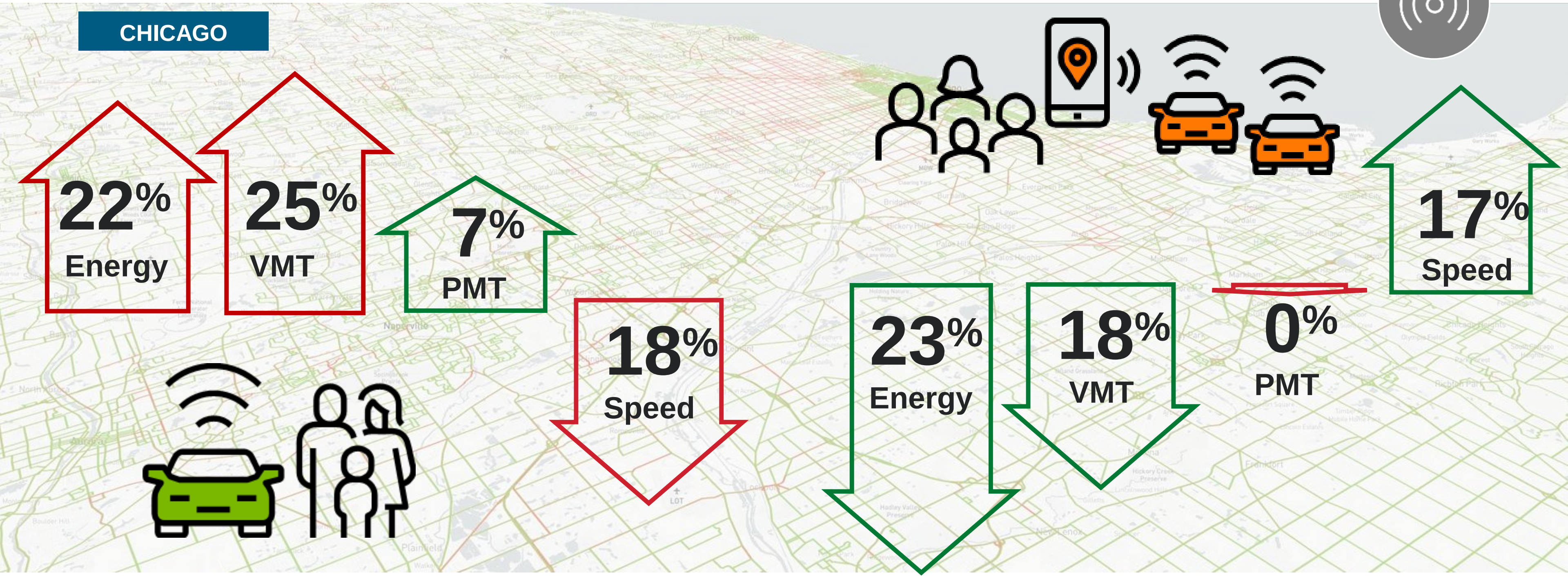
	Sharing		SAV		Private-AV	
Factor	BAU[3]	VTO[4]	BAU[3]	VTO[4]	BAU[3]	VTO[4]
VMT	-12%	-12%	-18%	-18%	4%	25%
PMT[1]	-1%	-1%	-2%	0%	-1%	7%
Avg. Speed[2]	11%	12%	16%	17%	-1%	-16%
Vehicle Energy	-12%	-13%	-18%	-23%	2%	22%
MEP	34%	34%	51%	76%	23%	10%

MEP Increased under all scenarios

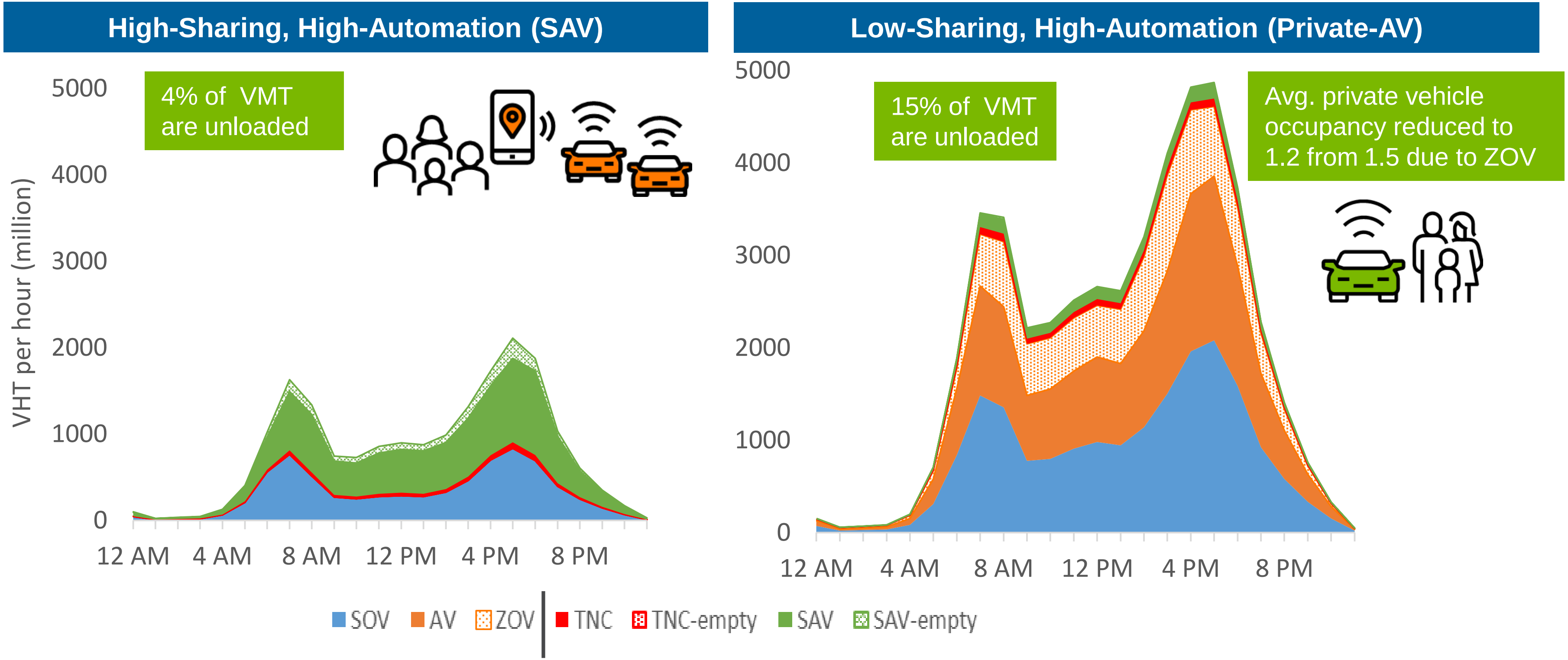
1. Productive miles of travel: Auto drive miles + passenger miles (by all modes) + freight miles – unloaded vehicle miles
2. Proxy measure for congestions; 3. PEV: Plug-in Electric Vehicles (PHEV + BEV) – Scenario Inputs
3. Business-as-usual vehicle technology development
4. DOE VTO program success vehicle technology development

SHARED FLEET CAVS ENABLE HIGH SYSTEM EFFICIENCY

Compared to personally owned CAVs



OPERATIONAL DIFFERENCES BETWEEN SAV AND PRIVATE AV ARE KEY



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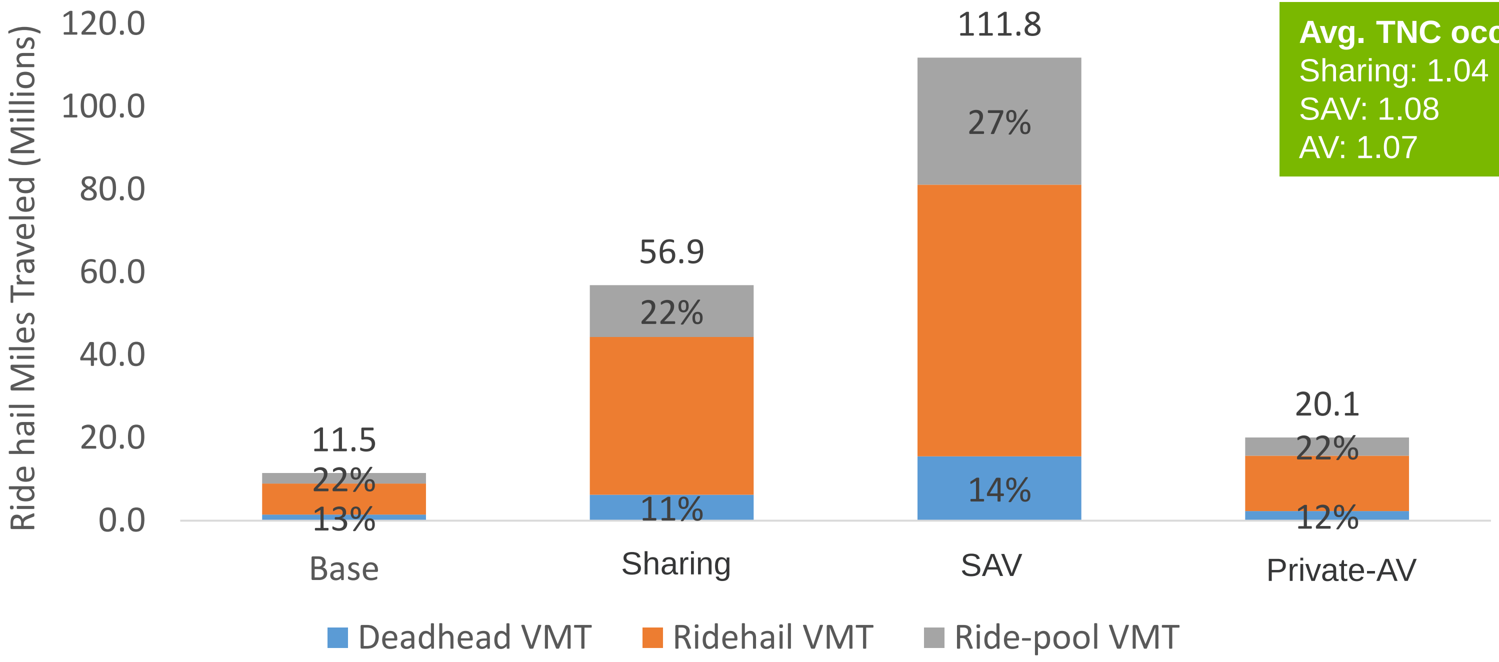
SHARING BENEFITS ENABLED BY EFFICIENT RIDE HAIL OPERATIONS

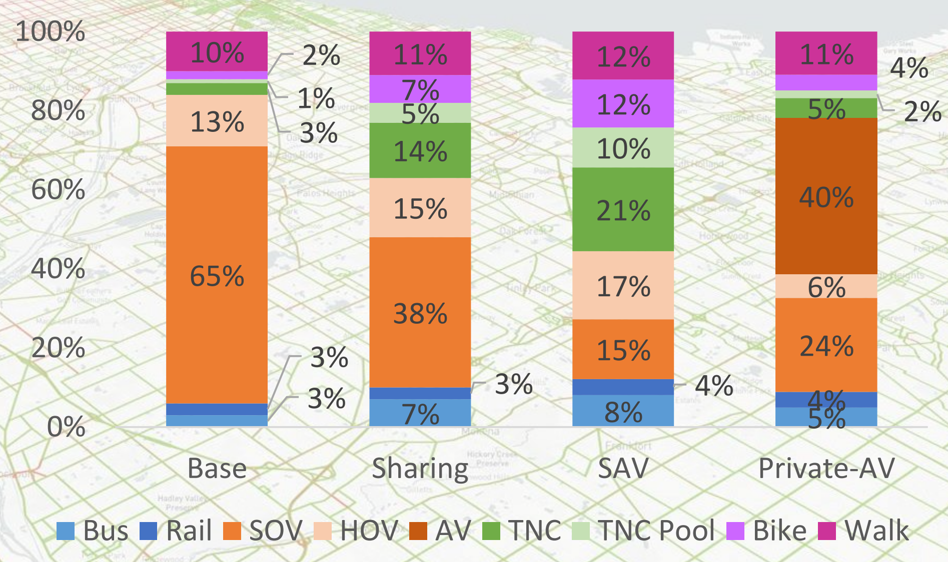


Avg. TNC occupancy:
Sharing: 1.04
SAV: 1.08
AV: 1.07

INDIVIDUAL TRAVEL BEHAVIOR CHANGES ALSO DRIVE OUTCOMES

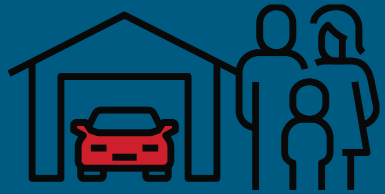
- **Transit use grows from 6% to 12% mode share as HH dispose vehicles**
- **Private-AV encourage additional SOV trips**
- **Urban households shift to transit, suburban shift to TNC if disposing vehicle**

Mode share substantially changes



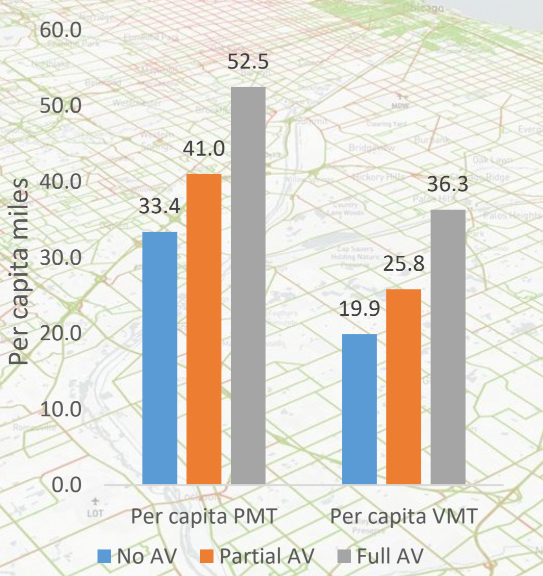
HOUSEHOLDS WITH AV BEHAVE MUCH DIFFERENTLY

Up to 82% VMT increase in households owning an AV

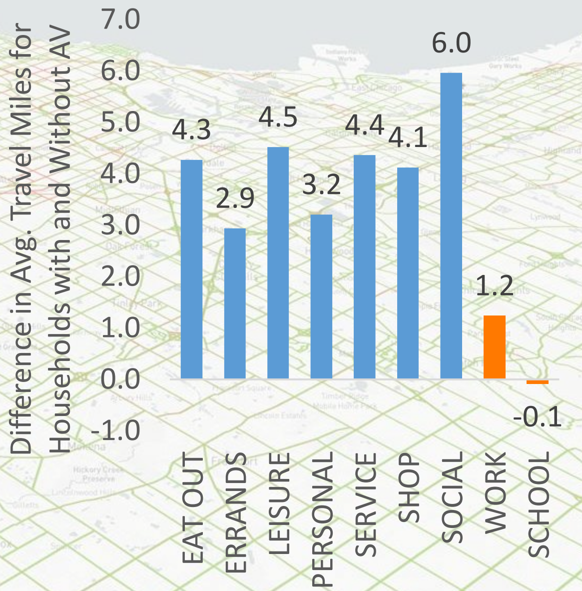


- Discretionary activity trips 3-6 miles longer (+30%)
- Additional trips concentrated in PM peak
- Persons with AV spend up to 30 minutes more in travel per day

Households with AV drive more than others



Driven by increased travel to discretionary activities



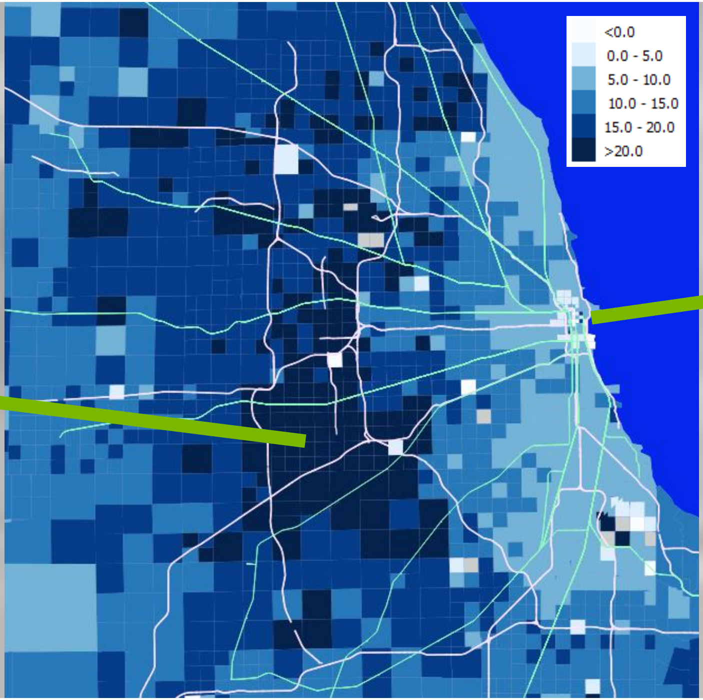
LOWER VOTT HAS GREATER IMPACT IN LOW-DENSITY ACTIVITY AREAS

Behavioral sensitivity of urban residents to VOTT change is low

CHICAGO

VOTT: Value of Travel Time
Monetary value I assign to an hour of travel; differs by mode, income, location

AVERAGE INCREASE OF
14 VMT
PER CAPITA IN CORE SUBURBAN AREAS (52% INCREASE)



AVERAGE INCREASE OF
5 VMT
PER CAPITA DOWNTOWN (38% INCREASE)

INCREASE IN E-COMMERCE LOWERS OVERALL SYSTEM VMT AND ENERGY

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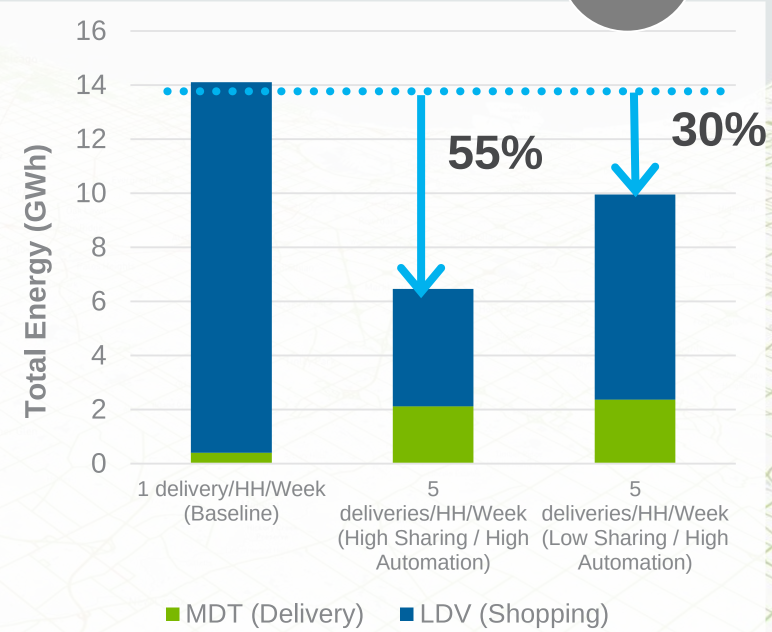
Fewer shopping trips, more deliveries make the difference

CHICAGO

SHOPPING TRIP = 7 to 8 miles, each way

DELIVERY TRIP **1 ADDED STOP = 0.4 mile**

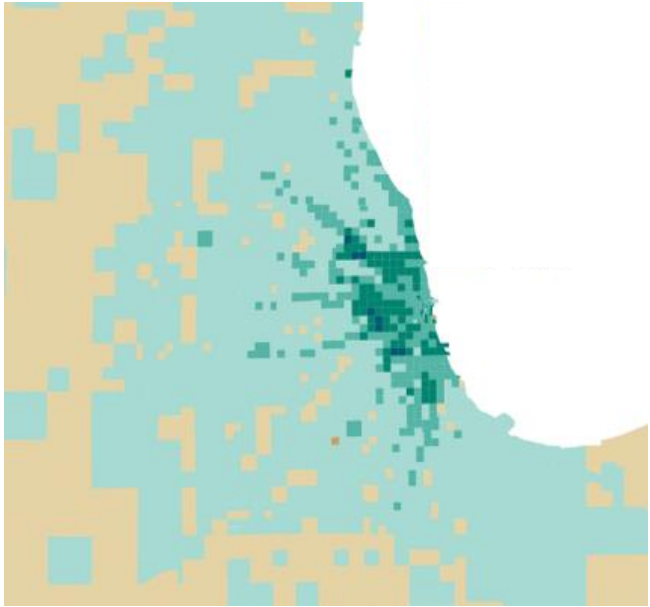


TRANSIT AND RIDE-HAIL CAN BE COMPLEMENTARY

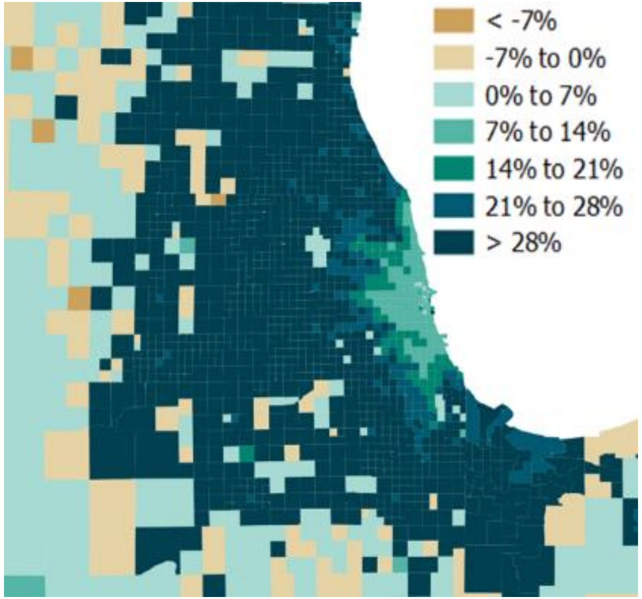
Transit is key mobility in urban core, TNC serves suburbs

- Transit ridership grows as vehicle disposal rate increases
- Increase in transit along hub and spoke lines, even as TNC increases
- Limited increase in TNC use in high-quality transit areas

Transit Mode Share change

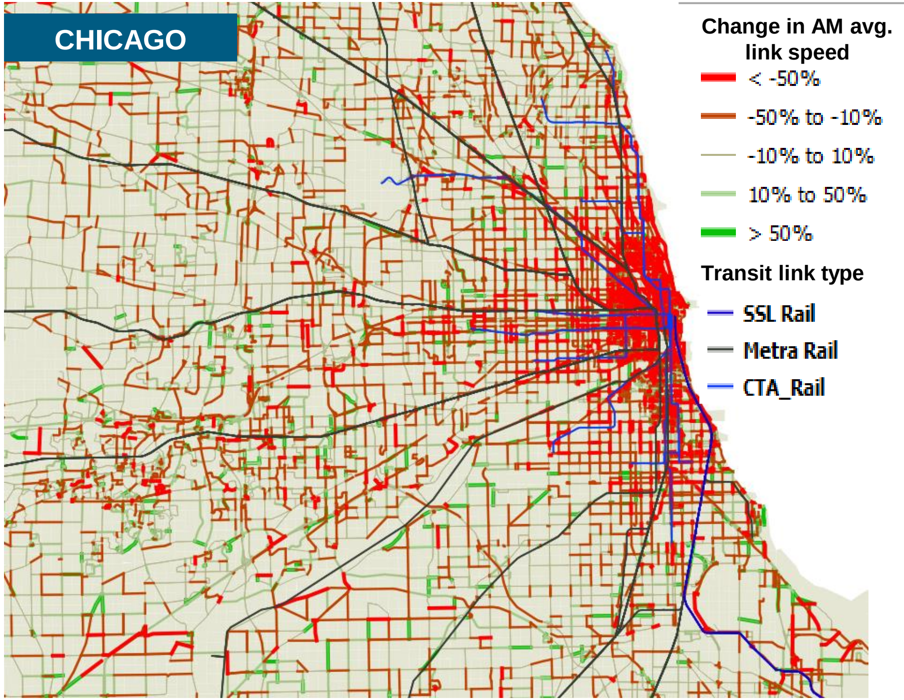


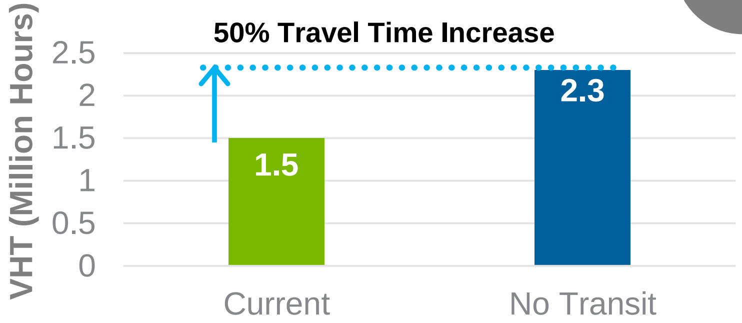
TNC Mode share change

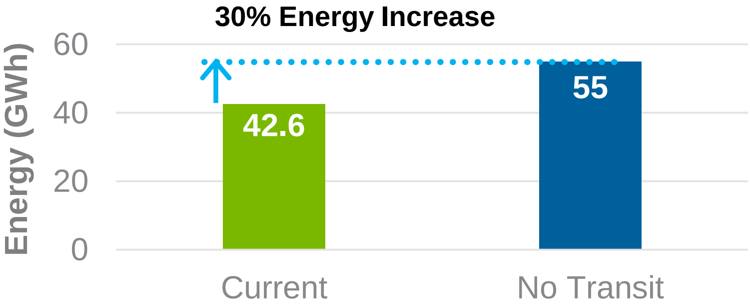


TRANSIT IS CRITICAL TO MOBILITY

Absent transit, energy use and congestion increase



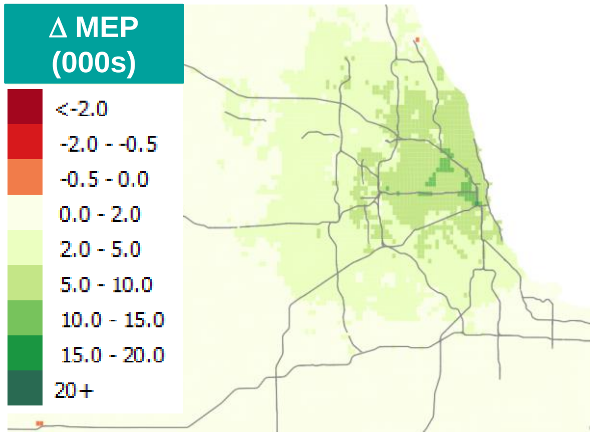




COMBINING MOBILITY AND ENERGY IMPACTS USING MEP METRIC

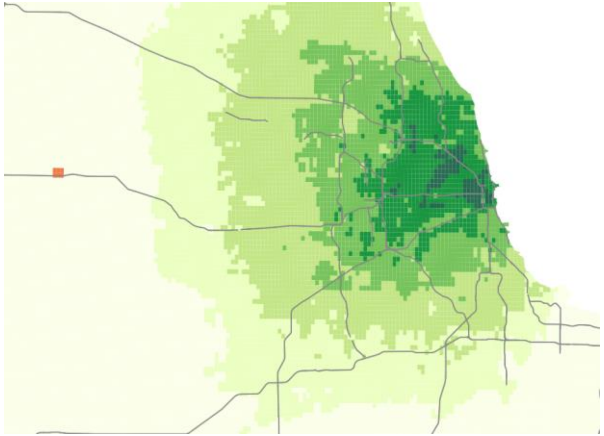
Disparate impacts depending on shared vs. private vehicle usage

Δ MEP: A (Sharing) vs. short term baseline



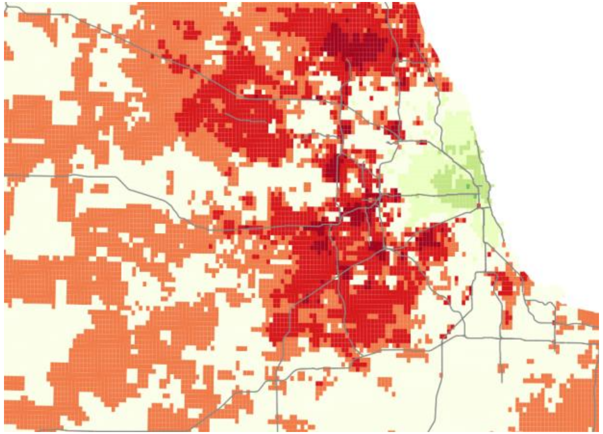
- Faster travel speed (+12%)
- Increased ridesharing
- Increased Transit use

Δ MEP: B (SAV) vs. long term baseline



- Faster travel speed (+17%)
- Reduced TNC cost and wait
- Concentrated in transit rich areas

Δ MEP: C (AV) vs. long term baseline



- Lower travel speed in suburbs(-16%)
- In Chicago, higher SAV fleet and transit use
- **Does not account for increased productivity during travel**

RESPONSE TO PREVIOUS YEAR REVIEWERS' COMMENTS

Reviewer Comment	Answer
The reviewer said the approach to validate simulation model is not very clear	Thorough validation including back casting presented (EEMS058)
The reviewer recommended a detailed sensitivity analysis to further quantify transportation choices.	Sensitivity analysis proposed under SMART 2.0 (need to have the workflow automated and deployed in HPC)
The reviewer would like to see the comparison results between POLARIS and BEAM.	POLARIS and BEAM results for the same scenarios but with different cities are available in the SMART Workflow Capstone report. Models for two common metropolitan areas (Detroit and Austin) are now being developed

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

U.S. Department of Energy SMARTMOBILITY	EEMS013, EEMS016, EEMS024, EEMS026, EEMS031, EEMS035, EEMS055
UNSW Sydney	Value of time and time use literature review Future work: time use analysis and scheduling behavior
The University of Illinois at Chicago	Activity timing choice models; mode choice modeling; activity generation analysis; Telecommuting behavior
Berkeley Lab	WholeTraveler survey data collection and analysis
Oak Ridge National Laboratory	Value of time analysis
CDOT Chicago Department of Transportation; CMAP	Local modeling and analysis stakeholders; data providers
Federal Transit Administration	Transit rider data collection and behavior analysis

REMAINING CHALLENGES AND BARRIERS

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Expand Workflow Capabilities

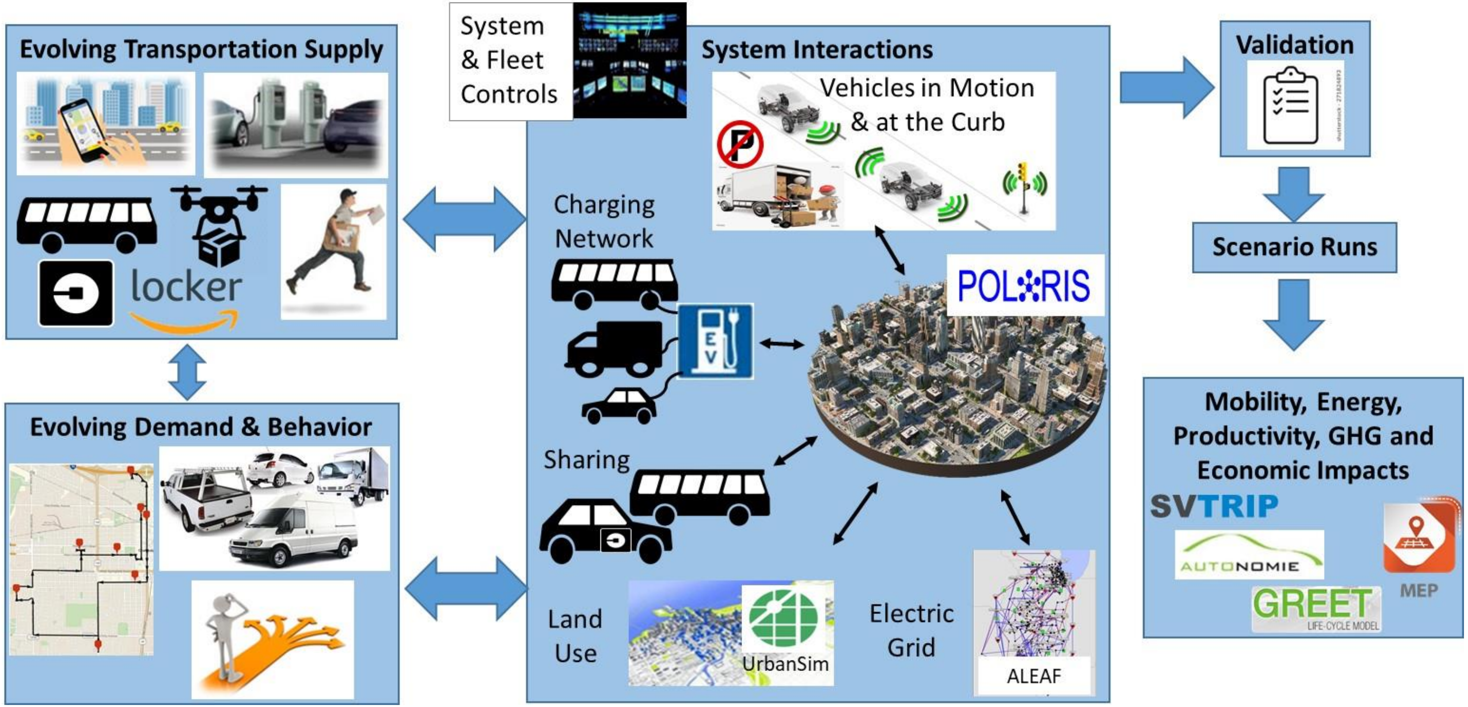
- Vehicle-to-anything (V2X) connectivity
- Vehicle automation
- Infrastructure management (e.g. ITS, traffic signal coordination)
- Transit route/schedule optimization, on-demand and micro-transit, TNC-transit integration
- Parking and curb space management
- Eco-approach/departure/routing and other control strategies
- Freight management and optimization under connectivity, automation and a changing demand environment
- Deployment and validation of SMART Mobility technologies…

Expand Workflow Applications

- What impact will shared mobility, micro-mobility, and multi-modal travel have on transit operations and overall transportation system efficiency?
- How will passenger travel behavior (incl. VOTT), change in response to new technologies?
- How will the ongoing reorganization of consumer goods distribution and new technologies in freight delivery impact regional mobility and productivity?
- How will electrification be implemented and what will be the impact regionally and on building and the grid?...

PROPOSED FUTURE RESEARCH

Significantly expand the number of scenarios considered and validate through deployment



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HIGH SHARING

12% REDUCTION IN VMT AND ENERGY

SHARED AV FLEETS

18–23% REDUCTION IN VMT AND ENERGY

PRIVATE CAVs

22% ENERGY INCREASE

TRANSIT USE

~67-100% IN TRANSIT RIDERSHIP UNDER HIGH SHARING

TRAVELER BEHAVIOR

82% MORE VMT IN HOUSEHOLDS WITH AVS

For any questions, please contact:
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SCENARIO DEFINITION COVER A RANGE OF POTENTIAL FUTURE SCENARIOS

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Variables	Baseline: Current / short / long term	(A) High sharing low automation	(B) High tech - mobility	(C) Low sharing high Automation
Private Ownership	98%	80%	46%	95% low tech/ 90% high tech
Auto VOTT factor[a]	1	L3/4: 0.7-1.0 L5: 0.35-0.7	L3/4: 0.5-1.0 L5: 0.35-0.7	L3/4: 0.5-1.0 L5: 0.35-0.7
Propensity for non-car modes[b]	1	0.5	1	1
Shared-use factor[c]	1.3	1	1	1.3 / 1.6 (no driver)
E-Commerce	0.08 deliveries per person-day	0.5 deliveries per person-day	0.5 deliveries per person-day	0.2 deliveries per person-day
Long Haul Freight Flows	1% CAGR[d]	1% CAGR	1.3% CAGR	1.3% CAGR
Vehicle Technology[e]	xEV penetration ~3%	xEV penetration 16-25%	xEV penetration 44-77%	xEV penetration from 44-77
L3/4 AV share[e]	0	10% - 11%	5%-8%	5%-8%
L5 AV share[e]	0	0	18% -52%	18% -52%
TNC / SAV fare[f]	$3.30 + $1.25/mile + $0.25/min.	$3.30 + $0.95/mile + $0.25/min.	$1.65 + $0.61/mile	$1.65 + $0.61/mile

a. Multiplier on the in-vehicle travel time for L3/4 and L5 AVs for all choice models. Varies by congestion level, time sensitivity of the trip and link type
b. Multiplier on travel time by non-car-based modes for all choice models
c. Multiplier on in-vehicle travel time for ride-share trips
d. Compound annual growth rate from baseline freight flows
e. Range is for low technology and high technology cases, respectively
f. Baseline is a mix of TNC/taxi pricing in Chicago. A is current day TNC pricing. B and C are SAV pricing (no driver charges + ownership cost per mile + 10% profit)